PERFORMANCE AND RISK ASSESSMENT FRAMEWORK FOR SUSTAINABLE NETWORKS

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Abstract: Nowadays, supply chains and specially Collaborative Networks are increasingly aware of sustainability issues and continuously seek to meet current human needs while preserving the environment so that these needs can be met not only in the present, but for future generations. In order to achieve this goal, particularly within Collaborative Networks, present decision making related with sustainability policies and practices, becomes a critical issue for the future of each stakeholder in the network. Sustainability networks must ensure that economic, environmental and social axes are fully aligned within each partner. To accomplish this, "performance metrics" for the entire network are required not only concerning the economic value of a business, but also in its environmental and social impacts. In line with this concept, organizations need to improve the quality of performance assessment namely in the sustainability areas. This paper focuses on this topic, presenting a new approach for performance and risk assessment within sustainable networks.

Keywords: Collaborative Networks; Performance Management; Performance Assessment; Risk; Key Performance Indicators; Sustainable Performance Indicators.

INTRODUCTION

Sustainability is defined as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'[1]. According to the UN 2005 World Summit it was noted that sustainability requires the reconciliation of environmental, social and economic demands - the "three pillars" of sustainability.

Particularly within Collaborative Networks (CN), present decision making related with sustainability policies and practices, is a critical issue for the future of each stakeholder of the network. Sustainability networks must ensure that economic, environmental and social axes are fully aligned within each partner.

Due to this pressure from stakeholders, "performance metrics" for the entire network are required not only on the economic value of a business, but also in its environmental and social impacts. In the context of CN, the performance metrics evaluation represents an important management challenge due to the heterogeneity present in the networks. Nevertheless, if successfully implemented, performance and risk assessment enables network managers to create enduring value for the multiple stakeholders in the network.

Increasing numbers of organizations report a massive volume of data, with low consistency and high variability in data quality, making it necessary to develop and implement new approaches for CN sustainable performance assessment. In line with this, organizations need improve the quality of performance assessment for the sake of both internal and external decision making.

This paper focuses on this topic, presenting a new approach for performance and risk assessment within sustainable networks.

PERFORMANCE MANAGEMENT

According to Sobotka and Platts [2], it is not possible to manage a process if we cannot measure its performance. In other words, performance management should be seen as an essential principle of management, because it not only enables the detection of gaps and bottlenecks in the processes (matching between current performances and desired performance), but also indicates where processes should be improved, namely in the sustainability issues, in order to fulfil these gaps and increase the overall performance of the factory or the entire supply chain. Hence, for sustainable companies, it is critical to determinate and select the key performance indicators, which, delivered to the right decision maker, can provide the crucial information to assure the factory processes improvement.

In fact, to achieve a useful performance management, it is required to the managers perform an exercise of balance between the interests of the supply-chain participants, knowledge about costumer's requirements, environmental factors and the business processes knowledge. Indeed, the choice of performance measures (economical, environmental and social) not only must integrate strategies, resources and processes but also should allow the its continuous improvement. In fact, this choice enhances the company to become more flexible and capable to adapt in real time to the continuously changing market and social demands.

Key Performance Indicators

In order to execute a performance analysis of a complex system, a preliminary step requires the structuration of the raw data available on the company. As result of this process performance indicators are generated. However, not all performance indicators are relevant to the system behavior analysis. It is necessary from the managers to define which are the key indicators to use according to their importance for the process. The key performance indicators (KPIs) are the input information to be analysed once captured by a performance measurement systems on the processes' output. The results obtained from this evaluation intends to be able to provide reliable information for decision making referring the necessary actions to problem solving, continuous improvement, process reengineering, or process innovation. In fact, the KPIs should be selected in order to support decision-makers improve the performance of processes in focus [3]. A linked concept is the key results indicator (KRI); which represent how actions are done in a perspective of a critical success factor. Other related concepts are the results indicator (RIs), or outcomes, that tell us what has been done; and the performance indicators (PIs), that tell us what has to be done. So, according to Parmenter, the KPIs "represent a set of measures focusing on those aspects of organizational performance that are the most critical for the current and future success of the organization".

The indicators establish the background foundation for understand the performance measurement and management system of an organization in its different perspectives. Firstly, it is important to define the performance management process regarding the information and data obtained from the performance measurement. Therefore this process comprises five stages: process output results, measurement inputs, results evaluation, decision making and improvement actions. In figure 1 it is represented the activities that can be related to each stage in order to execute the performance management process.

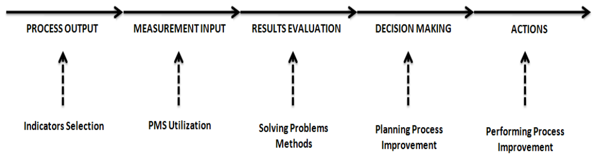

Fig. 1. Performance Management Process and correlated activities

In practice, activities such as selection of indicators, use of performance measurement system, solving problems through methods, improving the planning processes and improving the implementation of processes lead to achieving a better performance management cycle.

According to Franceschini, Galetto and Maisano [4], the indicators selection should be performed considering whether the results of the processes meet the needs of stakeholders, through an assessment system to test this condition. These indicators selection supports the decision to which strategies will be taken namely related to sustainability issues.

In order to define KPIs that meet sustainability issues, consumer expectations, regulation standards or goals to the organization, it is appropriate to use the process definition from ISO 9001: 2008: "an integrated system of activities that uses resources to transform inputs into outputs" (Franceschini, Galetto and Maisano, 2007, referring ISO 9001:2008 [4]. Adapting this description to the KPIs process definition and replacing the term "resources" to "requirements", it is possible to design a framework based on IDEF standard [5](Michel, 2002) to direct the definition and choice of KPIs. In the Figure 2 the modelling function IDEF0 is presented for the KPIs definition.

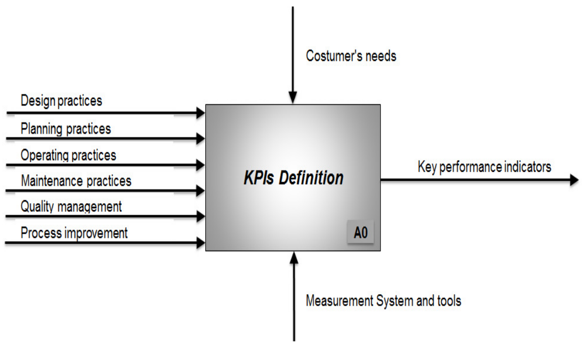

Fig. 2. KPIs definition through process concept

Sustainable Development

Making the concept of sustainable development operational for Collaborative Networks bring up important challenges in terms of measurement and assessment. Without indicators or a quantitative framework, CN decision makers seeking sustainable development policies inside the network lack a solid foundation on which to proceed.

As stated previously, the concept of sustainable development includes three dimensions: economic, environmental and social. Yet according to Candice Stevens [6], between these three dimensions there are complex synergies and trade-offs among them (see Figure 3).

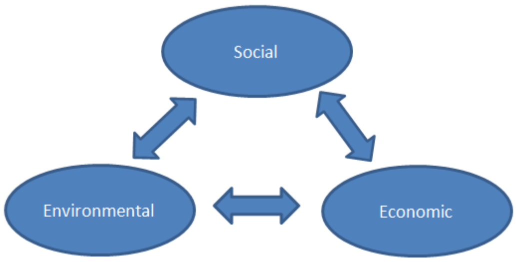

Fig. 3. Key dimensions of sustainable development [6]

Included in these synergies and trade-offs among the CN surroundings it is possible to identify the following effects:

1. Effects of economic activity on the environment such as resource consumption, waste volumes and pollutants discharge.

2. Effects of economic activity on society such as economic growth, income levels, employment and support for social services.

3. Environmental services to the economy such as provision of natural resources, sanitary landfills, contributions to economic efficiency and employment, human resources technological training.

4. Environmental services to society such as access to resources and facilities, contributions to health, quality working and living conditions.

5. Effects of social aspects on the environment such as environmental education, demographic changes, consumption patterns and environmental awareness.

6. Effects of social aspects on the economy such as labour force, population and residential structures, education and training skills.

To proceed towards sustainable development, companies and specially CN seek to follow policies aimed to increase economic efficiency and material wealth usage in order to take into account social and environmental objectives. Clear in this concept is a focus on inter-generational equity, implying that future generations should have same opportunities to those now available.

There is a consensus that sustainability indicators are needed to evaluate the longer-term implications of current decisions and behaviours from managers and to monitor progress towards sustainable development goals.

In simple terms and concerning an inter-firm view from the economic perspective, sustainable growth is the realistically attainable growth that a company should keep in order to maintain the risk in a controllable range, without achieve a no-return point. Indeed, a business that grows too fast may find it difficult to fund the growth while a business that grows too slowly, or not at all, may stagnate and cease to be competitive.

Therefore, one of the main challenges becomes finding the optimum Sustainable Rate (SR). This is the maximum growth rate that a company can sustain without having to increase financial leverage without affecting the environmental and social dimensions. In summary, in order to find a company's SR, it is primarily necessary to respond to the following question: how to measure and manage a single company and/or collaborative network growth in a sustainable way?

Despite the importance that this issue represent for the nowadays companies, achieving this goal is not an easy task, given the rapidly changing political, economic, market competitiveness. In fact, each of these areas presents unique challenges to business managers searching for the elusive grail of sustainable growth.

Moreover, CN stakeholders contend that achieving the excellent SR is not possible without take into consideration two main internal aspects: growth strategy and growth capability. Companies that pay inadequate attention to one aspect or the other are destined to failure in their efforts to establish practices of *sustainable* development (although short-term gains). After all, if a company has an excellent growth strategy in place, but has not committed the necessary resources to execute that strategy and have not considered the social and environmental dimensions, long-term development is unachievable. The reverse is true as well.

Therefore, due to the enormous quantity of information available for each of the sustainability dimensions, it becomes essential to select the critical data that helps decision makers to make the right decisions. Thus, we can define these critical data after processing as Key Sustainability Indicators (KSI).

Although the heterogeneous nature of the different companies within CN, network managers, are forced to define a global and homogenous strategy coherent for the entire network. Based on this premise, the KSI must be selected according to the overall strategy and applied to the entire network.

In sum, the definition of a sustainable development model goes together with the selection of the relevant KSI. This concurrent approach is particularly helpful in guaranteeing the system monitoring, while managing its sustainable development. Therefore, the implementation of a detailed, extensive and well-fitted sustainable development model becomes a crucial tool in order to reduce the risk impact of present decision in a medium and long term.

Yet simple and easily-understood indicators that do not compromise the underlying complexity of sustainable development have been difficult to define. Measuring sustainable development requires both simple measures that inform network decision-makers about relevant performance factors but also more detailed measures to support in-depth analysis. It is also important to have a double perspective about these measures, by given attention not only to the "supply side" (how statistics and related indicators can best be constructed) but also to the "demand side" (how these indicators can be translated and used most appropriately).

RISK ASSESSMENT

During the entire life cycle of Collaborative Network, it is necessary to not only to monitor the overall performance behaviour and sustainability development but also to analyze and assess the risk posed by the decisions made by the different stakeholders.

Indeed, a risk assessment program must be more proactive than reactive during the entire Collaborative Network life cycle. A proactive risk assessment must influence the Collaborative Network design process before the process begins. This approach should incorporate safety features with minimal cost and social/environmental impact.

The concept of controlling risk is not new. Lawrence [7] in 1976 had discussed the topic. He stated that "a thing is safe if the risks are judged to be acceptable". Recent discussions have focused with the risk associated with potential damage or degradation of system performance. Since risk is an expression of probable loss over a specific period of time, two potential variables, loss and likelihood can be considered as the control parameters. To control risk both the potential loss (severity or consequence) and its likelihood are addressed. A reduction of severity or likelihood will reduce associated risk.

As stated by Pecht [8], a critical and time consuming activity that must be performed from the inception of collaborative network business model is the risk assessment. Indeed, from the partner's selection, throughout the external logistics and processes definition, till the CN operation, it is vital to evaluate and assess the risk linked to each decision.

From the risk analysis it is possible to achieve a series of goals regarding the sustainability development of Collaborative Network. Therefore it is important identify the actions that can be taken to guarantee the alignment of the three sustainable dimensions and keep high performance rates at long term periods.

In the context of a Collaborative Network risk analysis, it is fundamental to obtain and analysis quantitative values, including uncertainty, not only for each collaborative process but also for the entire network. Thus, the identification of the important contributors to uncertainty and their characterization presents an important add-value once it enables the identification of the potential risk reduction actions.

The risk assessment program results are directly related with the Collaborative Network life-cycle phase in which the analysis is performed. For example, a preliminary risk analysis should be completed at time to influence the partners selection and tasks allocation. Therefore, this preliminary risk analysis should be performed prior to the preliminary Collaborative Network design. The objective is to use risk analyses diagnosis in time to be beneficial for the CN managers decision-making. This risk assessment program is also important in order to the Collaborative Network achieve sustainable development.

SUSTAINABILITY INDEX FRAMEWORK

Frameworks are important to structure work on indicators and on underlying performance. Because sustainable development encompasses three different dimensions and their interactions, there is a vast range of relevant indicators requiring a reference model in order to be framed in an organised structure. A sustainability indicators framework should be simple and understandable so as to link the indicators to management decision and performance evaluation.

Following the approach presented earlier, it is now important understand how it is possible to develop a tool capable of merge the different dimensions of the Key Sustainability Indicators and calculate a global Sustainability Index.

Primarily, it is important for CN managers to understand that for each economical, environmental and social dimension implicitly there are more than one KSI. Secondly, due to the subjectivity and non-deterministic nature of most of these indicators a modelling difficulty arises. Therefore, presented this heterogeneous and ambiguity scenario it is adequate to use a Fuzzy Logic technology capable of analyse each of the key indicator and retrieve the assessment corresponding to each dimension. This fuzzy logic analysis can be performed through the use of the equation represented in figure 4. In the sustainability index fusion equation each of the vectors contain the real values measured for each of the KSI. This vectors are used as inputs for the fuzzy system that in turn will be responsible for its compilation.

$$\begin{bmatrix} \begin{bmatrix} KSI_{Econ1} \\ KSI_{Econ2} \\ \cdots \\ KSI_{EconN} \end{bmatrix} \\ \begin{bmatrix} KSI_{Amb1} \\ KSI_{Amb2} \\ \cdots \\ KSI_{AmbN} \end{bmatrix} \\ \begin{bmatrix} KSI_{Soc1} \\ KSI_{Soc2} \\ \cdots \\ KSI_{SocN} \end{bmatrix} \end{bmatrix} * \left[f_{Fuzzy}(KSI_{Econ}), f_{Fuzzy}(KSI_{Amb}), f_{Fuzzy}(KSI_{Soc}) \right] = \begin{bmatrix} Assess_{Econ} \\ Assess_{Amb} \\ Assess_{Soc} \end{bmatrix}$$

Fig. 4. Sustainability Index Fusion

Lotfi Zadeh introduced the Fuzzy Logic in 1960, in order to respond to problems with non-probabilistic uncertainties [9]. Since the beginning, fuzzy logic technology has been widely applied to support decision-makers in the classification of complex problems. Fuzzy Logic is the opposite of certainty and precision. Indeed, this technology is normally used when there isn't quantitative detailed knowledge and uncertainty is significant in the system to be analysed. Moreover, fuzzy logic is presented as an interesting tool to model non-linear systems, which are very common in the real world. With this non-linear system model, it is possible to achieve a higher definition, diminish the modulation error and characterize more complex systems. The supporters of this tool argue that everything that cannot be clearly defined is classified as fuzziness, therefore the adequacy of this approach. The Fuzzy system model is divided into four main stages according to Figure 9.

The fuzzyfication process specifies the system's fuzzy inputs mapped in qualitative outputs.

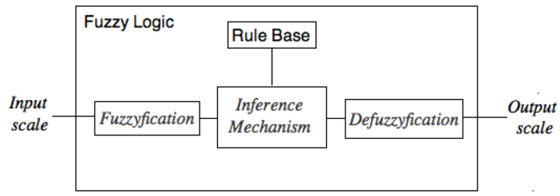

Fig. 5. Fuzzy Logic Schema

Each fuzzy variable is set up by states, which are sets that have a membership function associated. In a simplified way, a membership functions can be seen as a graphical representation of the magnitude of each input's participation. Then, in order to normalize the KSI inputs in the image of the network system, it is essential to have relevant knowledge about the impact of each KSI on the system that will be modulated in order to setup the fuzzy logic control.

Indeed, dependent on the impact of each KSI value oscillation, the system manager can tune the membership function in order to represent this impact factor. For example, as depicted in the graph represented in figure 6, the behaviour produced by the B2 curve is much more reactive than the one produced by the B1 curve. This can be easily observed in a real scenario, in any of the sustainable dimensions. Taking the environmental dimension as example, it is well known that the impact of the CO2 within the environment condition, despite negative, is lesser harmful than methane. Therefore, taking this as knowledge base, the production system manager can tune each of the behaviour curves in order to describe and distinguish the impact caused by a little oscillation in both cases.

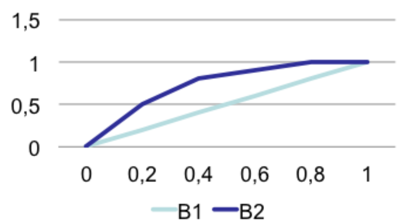

Fig. 6. KSI Impact Behaviour

To compile the knowledge existing about relationship between the different KSI for each sustainable dimension, normally represented by output linguistic values, a rule matrix is used (e.g. "if X is very high, and Y is high, then Z is very Low"). When the rules matrix that model the system and support all the combinations possible between the KSI are defined, it becomes critical to define the contribution of each rule for the fuzzy system, using for example the Mamdani-type. In the following picture (see figure 7) it is possible to visualize the main steps described previously.

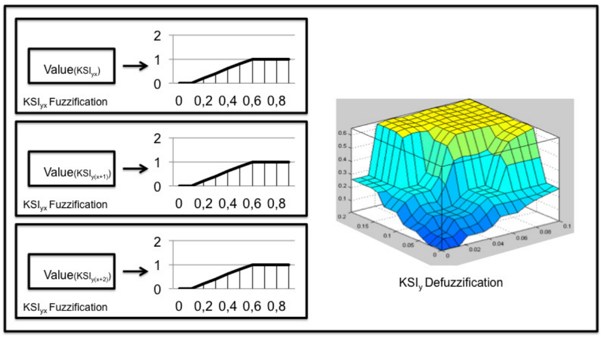

Fig. 7. Overall Framework

In order to get the fuzzy result, it is necessary to translate the variable fuzzy states into real and concrete values (defuzzyfication process). In order to perform this operation it is usually applied the centre of gravity method, also known as centroid. This method consists of calculating the fuzzy set mass centre. At this stage, it is already available the assessment value for each of the sustainability dimensions. However, in order to calculate the overall Sustainability Index, it is necessary to perform a final estimation. The SI value is equal to the multiplication of each of the assessment dimensions, as presented in the equation of the figure 8. Because this formula is based in a multiplication, deficiencies or low indicators values in any dimension are severely multiplied producing an overall more balanced evaluation.

$$SI = Assess_{Econ} * Assess_{Env} * Assess_{Soc}$$

Fig. 8. Sustainability Index Formula

As it is possible to observe from the defuzzyfication, the different plots that compose the SI calculation at final stage are used as if they pose the same importance for the overall network sustainability. However, this only can be true, because during the fuzzification process, the network manager has the chance to define the membership functions and, therefore the corresponding importance and impact for the overall network sustainability.

This type of calculation for SI results in severe values if one or more of the sustainability dimensions are low, emphasizing the need to guarantee the improvement in all three dimensions of sustainability.

CONCLUSIONS

At the core of sustainable development is the need to consider "three dimensions": social, economical and environmental. No matter the context, the basic idea remains the same, people, habitats and economic systems are inter-related. It is common to ignore this interdependence for short periods of time, but history has shown that before long, mankind is reminded of it by some type of alarm or crisis.

Especially in new type of organizations such as Collaborative Networks, the sustainability issues arises as relevant in performance evaluation and risk assessment for the survival of the network.

In line with this, the current work presents the main concept and vision of the Key Sustainability Indicators as means to evaluate the longer-term implications of current decisions and behaviours in CN. These can be seen as special key performance indicators that should be capable of expressing the behaviour of a network in three described dimensions: Environment, Social and Economical.

In order to compile all the data referent to each of the sustainable perspectives, this paper presents a framework that supports not only the KSI selection, but also the Sustainable Development index calculation. Indeed, with this information, it is possible to introduce a useful measure capable of support decision makers evaluating if the CN is achieving sustainable development. Moreover, this framework is capable of providing a benchmark mechanism, to help managers comparing and assessing different networks in a coherent way.

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